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Accessibility in video games: a Systematic Review

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Abstract. *Context:* Video games are software products with several purposes that are growing in strength and weight in society. However, there is one noticeable problem about them, in most cases, their developers most often do not take into consideration people with disabilities when they are creating video game applications. People with disabilities are thus partially or completely excluded from their use. Prior to any additional work, it is required to have an updated state of the art about this topic. *Purpose:* This paper shows the results of a Systematic Literature Review conducted to define the current status of video games accessibility. *Methods:* The type of review is broader than usual, so it is a Systematic Mapping Study (a specific class of systematic review). *Results:* Besides elaborating the state of the art (qualitative information), we identified and analysed related works (45 relevant studies) to provide quantitative information of the performed search (including graphs and tables), such as the number of articles found by phases, their sources, their research type, the research questions answered, the kind of disability addressed, the type and year of publications. *Conclusions:* None of the studied initiatives can guarantee universally accessible video game applications. Our proposal is to create an integral software engineering methodology that considers accessibility guidelines, techniques, strategies, human factors, etc. in the video game software development process.

Keywords: Video games; Accessibility; Human-Computer Interface; Systematic Mapping Study; Systematic Literature Review; Interdisciplinary projects

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1 Introduction

People often use video games as a means of evasion and amusement. In fact, they are a prevalent form of leisure in the 21st century [10, 42, 51] and constitute the industry of digital entertainment, which is in full swing [11, 35, 52].

Although these products may have adverse effects and have been criticized for causing addiction and violent behaviour, there is no conclusive scientific evidence to date to prove this fact [18] and, they have been observed to have positive effects. The main ones are their ability to motivate people, facilitate learning and promote the personal development and mental/physical rehabilitation. For this reason, video games are used for purposes that go beyond entertainment [7, 14, 19].

However, accessibility barriers within these products have made them almost unusable for people with disabilities, leading to their exclusion from this social phenomenon [4, 9, 34, 43].

Technological innovations of all kinds (Hardware and Software) emerge continuously in order to palliate these barriers (cell and smart phones and tablets, Web features, new interfaces, frameworks, guidelines, etc.), though there is still much work to do to reach an equivalent and efficient access to SW applications (including video games), where apps can be used by people with very different skills and profiles.

The authors, considering the problem described, have performed a Systematic Literature Review (SLR) with to assimilate and reveal relevant ideas that avoid the exclusion of users with functional diversity in the future development of video games.

A systematic review is “a review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review” [36]. In the specific case of the present review (illustrated in Figure 1) we considered both the guidelines for performing systematic literature reviews in software engineering [28] and the principles of the PRISMA Statement for Reporting Systematic Reviews [33].

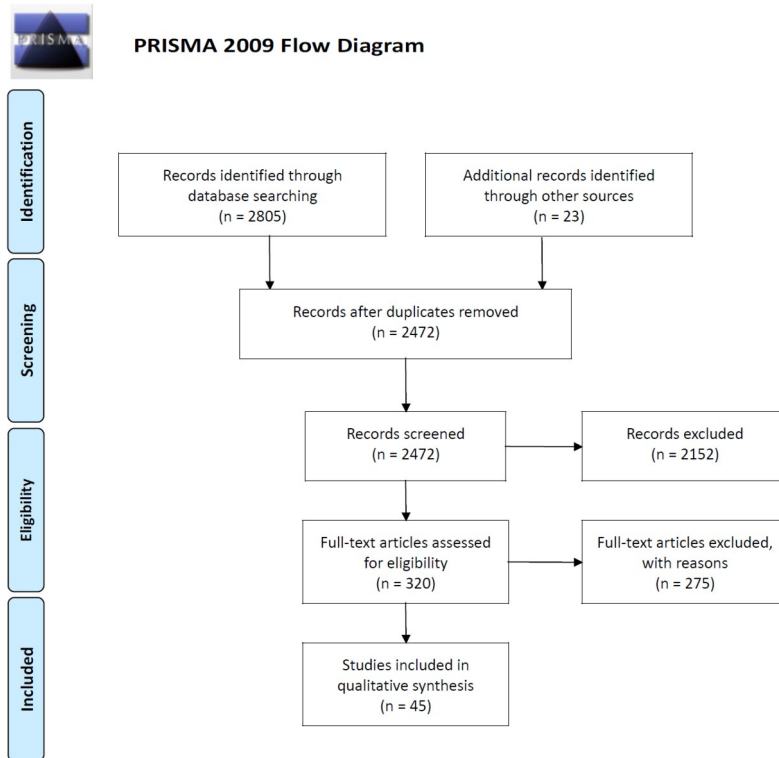


Fig. 1. PRISMA flow diagram of included studies [36]

An SLR has been carried out because it enables the researcher to express the state of the art in this field describing the process of investigation in a rigorous manner. Given the characteristics of our investigation (a low level of specificity, with general research questions to reveal a broad vision of the area of study), it can be considered a Systematic Mapping Study (SMS) [27].

Despite the authors discovering works that reveal the current state of the video games in relation with Software Engineering [1] or in relation with Health [31], it is important to stress that no previous documentation of these characteristics (SLR or SMS) based on the study of the accessibility of video games has been identified, which gives an additional reason to perform this research.

The primary aim of this study is to reflect the current state of the literature regarding accessibility in video games, identifying the primary studies in the said specific literature related to the area and synthesizing the basic concepts.

Based on data collected, the authors offer a view of the problem (classifying the studies in categories), identify existing shortcomings and suggest possible solutions or research lines, all of which can be very useful to field researchers when it comes to postulating new improvements. As such, the description and the suggestions put forward would be the contributions made by this study.

This paper is organised in the following manner: section two includes the state of the art of the field of study, the approach followed in the investigation is described in section three, the results obtained are analyzed in section four, in the fifth section a brief discussion of the area based on the above is outlined and, finally, the main ideas are described in the conclusions section.

2 Foundations of accessibility and video games (state of the art)

The last step of SLR, reading of the documents, has allowed us to condense the state of the art of the field (qualitative information) including a theoretical base (a conceptual compendium) of three areas closely linked: accessibility, video games and the accessibility of video games. This section is divided into three subsections (corresponding to the areas previously listed) to limit and define every research field.

2.1 Accessibility

According to the law of equal opportunities, non-discrimination and universal accessibility for people with disabilities (Spanish organic law 51/2003, from December 2, 2003), accessibility is defined as the condition to be met by environments, products and services to be understandable, usable and workable for all people.

There is a strong desire in society to make progress in this area, as evidenced by the existence of statutes in the laws of many countries (including Spain) that seek to ensure equal opportunities and access to content [6].

Regarding accessibility in the media, remarkable growth in recent years can be reported thanks to the emergence of laws that promote a more inclusive society and recognize the universal right of access to culture and leisure [34].

This is especially noticeable in other software platforms, such as the WWW. Technological enhancements aimed at environment improvement for the disabled had usually focused on Web accessibility and assistive technologies [43, 51].

2.1.1. Disability and its types

A disabled person is defined by the Oxford English Dictionary as one who has a physical or mental condition that limits their movements, senses, or activities.

The International Game Developers Association, in [6], affirms that a large percentage of the population (10-20%) suffer some congenital or acquired disability, reinforcing the conclusions of [30] (where it is stated that the World Health Organization estimates this figure at around 10%). This percentage will grow over time because life expectancy is increasing [40] and when people get old they often develop deficiencies (deafness, vision problems, etc.) that they have not previously suffered [12, 51].

As the number of disabilities is growing and their characteristics are complex, it is beneficial to use a classification, with which we will be able to sort the studies reducing the types of disabilities to a limited number. Figure 2 shows the classifica-

tion of disability (in relation to video games), defined considering [4, 6, 30, 52], that is proposed in this work.

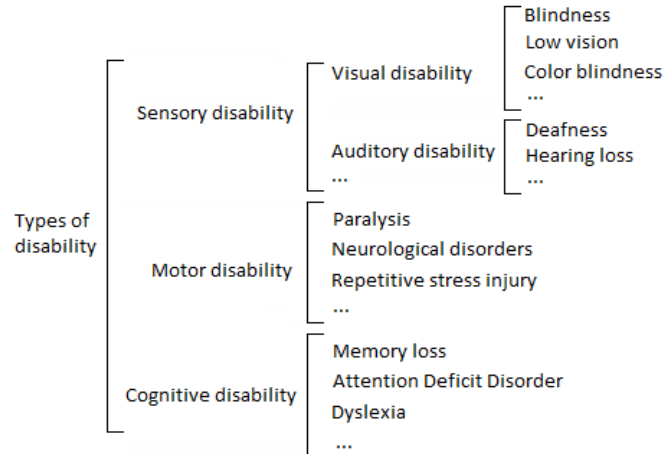


Fig. 2. Proposed taxonomy of disabilities for video games context

2.2 Video Games

According to [18], video games are computer programs designed for entertainment and fun that can be used via various platforms, such as video game consoles, computers or mobile phones.

The same publication reveals that video games have not stopped evolving and growing since their inception (1950-1960).

Much of this evolution exists thanks to new technologies and their introduction in society. These have changed the way we communicate and interact, our social habits and how we understand leisure. Video games have become important products, increasing their resources, sophistication and variety. The figures of this sector, which even surpass the numbers of other relevant industries like film or music [11], are a clear reflection of their potential.

Finally, we also note that some video games have been developed to meet additional purposes than leisure [35], such as educational or rehabilitation plans.

2.2.1. Video Game genres and interaction model

It is important to analyze the existing types of video games and the interaction model, both obtained from [52].

According to this publication, it is possible to highlight the following genres: First-person Shooter (FPS) games, Strategy games, Sports games, Role-playing Games (RPG), Puzzle games, Racing games, Dance / Rhythm games and Adventure games.

The interaction model (a cycle which governs the use of any video game) is a process that is repeated until the game ends: receive stimuli (visual, auditory or tactile), determine response and run an entry through the relevant interface.

The lack of accessibility in a video game is usually caused by it being difficult or impossible to complete any of its phases:

- 1st phase => the player cannot capture stimuli [sensory disability]
- 2nd phase => the player cannot determine responses [cognitive disability]
- 3rd phase => the player cannot properly use the input interface [motor disability].

2.2.2. Video Games in learning

Several scientific studies have been published in recent years addressing the use of video games for educational purposes.

Such is the case of [35], where it is stated that several educators (as Dewey or Piaget) are intrigued by the idea that playing can improve understanding and inspire the creation of stimulating environments. This approach reveals the games as a means to educate through motivation (concealing their teaching purposes beneath the properties of products and personalizing the experience). This concept is evident in Serious Games, based on entertainment though with a purpose other than purely recreational [3].

For example, Kinect is a practical, affordable and appropriate technology to enhance the educational process [48], which can also be used (in conjunction with specific video games) to promote learning in children with mild autism [7].

2.2.3. Video Games in rehabilitation

It is also possible to find research that relates video games with functional rehabilitation (physical or mental) of patients.

For example, Autism Project [45] facilitates a customized rehabilitation process for autistic children through a sequence of **adaptive OR adaptable** games.

The Serious games based on user movement are a good alternative to complete plans for rehabilitation of people with motor disability. Evidence of this is Kinect-o-Therapy [44], a system which includes routines to exercise different parts of the body in an entertaining and motivating way (with minigames), providing a pleasant - rather than therapeutical - experience for the patient.

Thus, the use of video games applied to the field of disability has great potential as a tool for rehabilitation [10], considering a wide range of cases such as the elderly [14] or individuals with cerebral palsy [19].

2.3 Accessibility in Video Games

The Game Accessibility Special Interest Group (GA-SIG) of the International Game Developers Association (IGDA) defines accessibility in video games as the ability to play even under restrictive conditions, because of functional limitations or disabilities, for example, sensory or motor [34].

So far little interest has been shown in developing titles that can be potentially used by all players [22], since accessibility in video games (cultural products in Spain since 2009) has received scant attention from both industry and academia

[34]. The positive aspect of this issue is that this trend has changed in recent years [21], which has led to the emergence of all kinds of proposals and related research.

Mainstream video games are far from being accessible because, as Porter stated in [42], the professionals of the sector do not take into account advances provided by the main research within the field of Human-Computer Interaction (HCI) (unlike, for example, of what happens in the Web environment).

Despite the efforts seen in recent years, more substantial investments need to be made to guarantee universal and equal access to video games and raise society's awareness of the need to achieve this goal [34].

2.3.1. Hardware progress

One of the most common proposals to try to facilitate the use of applications and/or video games for people with disabilities is the use of assistive technologies that ease existing barriers in these products. Thus, the emergence of new interfaces that deviate from the traditional model involves new forms of interaction (eye movements, brain activity, etc.) and predicts the possibility of achieving higher accessibility [24]. Within this line of research it is possible to find:

- eyeCan: a system that provides precision and variety in capturing gaze gestures (eyes and eyelids), with which it is possible to use sophisticated applications (such as video games) [32];
- EPOC: a brain-computer interface (BCI) which, through an electroencephalograph, an electromyograph and a gyroscope, gives people with limited motor skills the ability to manipulate applications and video games with acceptable accuracy [41];
- Kinect: a device that through body gestures permits access to and use of both generic applications and video games [19], utilising Natural User Interfaces (NUI), which have proliferated in recent years [46].

2.3.2. Software progress

There are also approaches from the logical point of view to accessibility in video games that can be found in the literature, as follows.

- Frameworks: frameworks and systems which provide support for the development to ensure that the product obtained will be accessible. Examples include the AGA framework [35], FFAST [46], GADF [47], Exertion Framework [39], KINECTWheels [15, 17] and RTSS [38];
- Aspects of Software Engineering: some publications introduce specific elements of Software Engineering.
 - *Guidelines*: sometimes a set of guidelines, strategies, recommendations, etc. are supplied to provide guidance during development to improve the accessibility of generated video games. There are several studies that focus on this goal, including [11], [52], [4], [6], [5], [13], [16] and [23]. There are also publications that specify applicable guidelines for cell phones and tablets (whose use is soaring), such as [30], [26] and [8];
 - *High-level*: specific studies define concepts related to the creation process of accessible video games, encompassing development stages sep-

arately or jointly. This is the case of the adaptation of the Unified User Interface Design method defined in [22] to design universally accessible video games or those proposed [2, 20] over the assessment of the accessibility level of video games;

- Accessible video games: there are both custom developed titles for audiences with disabilities and adaptations of existing video games through modification of the code (or inclusion of specific characteristics). This is visible in Blind hero [51], VI Bowling [37], Terraformers [49] and Tap-Beats [25].

3 Research methodology

To guarantee an acceptable degree of comprehensiveness in the review, it was decided to follow the principles established in most of the SLRs.

A literature review (secondary study) is defined as systematic if it is based on a set of clearly defined research questions, if it identifies and evaluates the relevant studies (primary studies), and synthesizes the basic concepts and evidence using an explicit methodology [29].

The first essential step was to study the existing SLR methodologies to choose and/or adapt the one which best suited our requirements. After the different options had been analyzed, it was decided to complete the process in the qualitative review modality. Following this approach, a meta-synthesis of the preceding works was carried out applying a consistent process, which involved peer review (with the surveillance of a supervisor) to achieve a search for references in a systematic manner.

In this way it is possible to study the majority of publications which can be useful to attain an acceptable and impartial knowledge of the field to be addressed (accessibility and video games, in this particular case), following guidelines of proven solvency which facilitate the search and guarantee a systematic and ordered method (which is easily repeatable).

After consulting the foundations included in the said bibliographic search system and selecting one of the different existing scientific methodologies, the steps to be taken to attain the desired objective (a robust and high-quality body of knowledge relating to the object under study) were clearly outlined.

Finally, to optimize the process for obtaining references, the recommendations and protocols contemplated in SLR have been interpreted and adjusted. A summary synthesizing each and every one of the steps followed is presented in the following (Figure 3).

1. Definition of search terms: the phase in which the fundamental research questions are formulated guiding the project and the search terms, which must be adjusted to these questions;
2. Identification of databases, search engines and journals: a stage focused on selecting the sources within which to search for the resources which will support the investigation (articles, conference proceedings, etc.);
3. Selection and application of filters to include or exclude results: in this phase, suitable filters to refine the search (broaden or reduce it) are selected

depending on the number and nature of the results provided by each source. In certain occasions, it is necessary to modify the filter options and repeat the search to verify the validity of the retrieved studies;

4. **Ensuring the representativeness of the obtained resources:** this is the final stage, in which the publications compiled are revised to check that the resources are the right ones and will guarantee a comprehensive coverage of the subject under study.

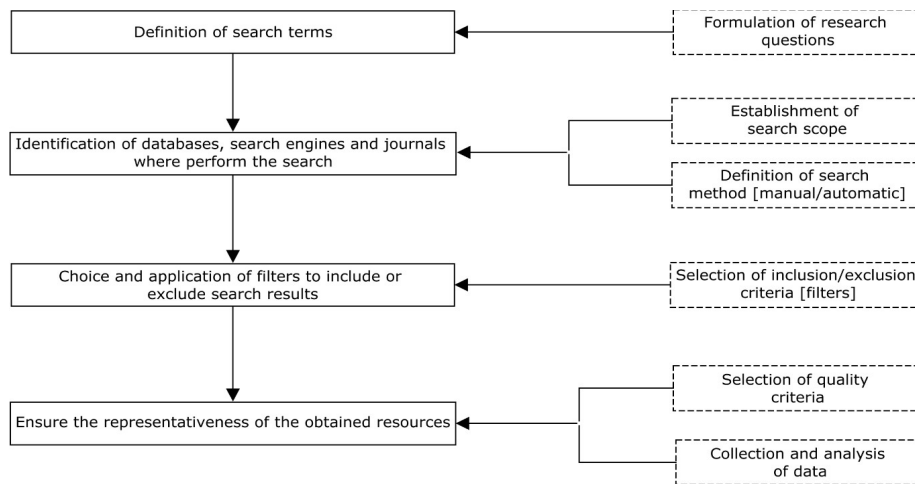


Fig. 3. Steps followed in the review process (review protocol)

3.1 Definition of search terms

The first step in any investigation always involves the definition of one or several clear and precise questions, which must be answered via reading of all the material compiled during the process.

Therefore, to concentrate the search on the requirements of our investigation, the following questions were defined:

- RQ1: Are video games being developed today truly accessible?
- RQ2: Have enough solutions been proposed in order to increase the accessibility of the video games being produced?
- RQ3: Could a specific development methodology arising from the adaptations and/or modifications of existing solutions have a notable impact on the level of accessibility of the video games?
- RQ4: Do the developers of video games appreciate the proposals and improvements previously suggested in terms of accessibility?
- RQ5: Is the pursuit of universal accessibility of video games a realistic, achievable and/or profitable aim?
- RQ6: Do video games provide any benefits for people apart from their entertainment value?

According to [28], the definition of the questions has been accomplished taking into consideration the following criteria: *population* (published scientific works related with accessibility in video games), *intervention* (studies which put forward and/or evaluate solutions [practices, techniques, methods and processes] in an empirical or narrative fashion), *comparison* (publications without clear solutions or with inappropriate approach), *outcomes* (all kinds of conclusions useful in the field) and *context* (both academia and industry).

Although all the questions are interesting, the first one will be the main research question due to the object of the study, which aims to discover the level of accessibility provided by the video games currently being developed.

At the end of this document, in the section of conclusions, a well-founded answer will be provided to every question, based on the study of the works analyzed.

After defining the central question, we must define the keywords or search terms that best fit the said question. These are the words that later must be consulted in the sources of the investigation (search engines and relevant databases). The terms chosen were *accessibility "video game"* (both in Spanish and in English) and other derived terms (like *accessible* or *"mobile game"*), since they clearly describe the fields involved. In this way, the results obtained are related to accessibility, with video games or with both at the same time.

Considering the above, the expression used in the search process was:

(accessibility OR accessible) AND ("video game" OR "mobile game")

In addition, the expression using the same search terms in Spanish was searched.

3.2 Identification of databases, search engines and journals

Once the terms involved in the search process are known, the next task is to determine where to carry out the search (research sources). In order to obtain valid results, the search engines and bibliographic databases selected must be prestigious and return publications related to the matter, clearly delimiting the scope of the search.

The said sources are *Google Academics*, the search engine of *Biblioteca de la Universidad de Alcalá (BUAH)* and the great majority of electronic resources in computer science: *ACM Digital Library*, *IEEE Xplore*, *SpringerLink*, *SpringerLink Books*, *Lecture Notes in Computer Science*, *AENORMás*, *ScienceDirect*, *Web of Science (ISI)*, *INSPEC*, *Scopus*, *Academic Search Premier*, *ArXiv.org*, *Documat*, *e-libro*, *ICYT*, *IGI Global InfoSci Books*, *INGeBOOK* and *MathSciNet (AMS)*.

In addition to employing these 20 reliable sources, in some cases, the search was complemented with a manual process, following referenced works within publications of more significant interest, discovering new relevant works. Thus, a hybrid search process has been performed, using both the results obtained automatically (from the years 2004-2014) and those chosen expressly by the authors due to their importance. Thereby, the relation between different works can be discovered and the way in which knowledge related to the area has evolved over time can be observed.

3.3 Selection and application of filters to include or exclude results

After defining the terms and sources to be consulted, in this step we complete the search chains over the selected sources to find the works which fit the field of investigation, filtering where suitable (using inclusion/exclusion criteria). Furthermore, when necessary, the filtering options are modified, and the search is repeated to ensure that the results obtained are correct and afford a comprehensive coverage.

The filters enable us to exclude unnecessary results though do not allow to include new ones, since the search terms are quite generic.

Although the searched terms have been the same, in each source a particular method has been followed, depending on the number and relevance of the results obtained, applying different kinds of filters (metadata of the title, author/s, date of publication, etc.) to retrieve only those works that are really interesting. Refining the search in this way was necessary, because some sources returned elements not related to the profile or the approach of this study (an approximation to the problem from the Computer Science point of view).

Thus, as the characteristics and properties of each source are different, it is necessary to specify the restrictions that have been placed on each one of them individually (see Table 1).

Table 1. Properties of performed searches over the consulted sources

Data source	Search settings	Applied filters
Google Academics	Sort by relevance and complementing automatic obtaining of publications through links to "Related articles"	Without filters
BUAH	Sort by relevance	<i>Type of publication</i> to "any", <i>Topic</i> to "any", <i>Publication date</i> without values, <i>Source</i> to "any" and <i>Language</i> to "any". It has decoupled the option "Exclude newspaper articles"
ACM Digital library	Sort by relevance	Considered both <i>Publications from ACM and Affiliated Organizations</i> and <i>The ACM Guide to Computing Literature</i> (Bibliographic citations from major publishers in computing)
IEEE Xplore	Sort by relevance and with Advanced Search, marking the option "Full Text & Metadata" and including all publishers, content types and publication years	Filtered the results according to <i>Publication title</i> , leaving out "Education Engineering (EDUCON), 2010 IEEE" and "Education, IEEE Transactions on" and marking the remaining elements
SpringerLink	Sort by relevance	Selected "Computer Science" as <i>Discipline</i> and "HCI" as <i>Subdiscipline</i> .

			The filtering process has been repeated with "Computer Science" and "Engineering" as <i>Discipline</i>
SpringerLink Books	By default		Without filters
Lecture notes in Computer Science (SpringerLink)	Sort by relevance		Without filters
AENOR Más	Sort by code		Without filters
Science Direct	Sort by relevance and writing the keywords in an input that considers all search fields (labeled as <i>Search all fields</i>)		In <i>Publication title</i> : -"Computers in Human Behavior". -"Computers & Education". -"Computers and Composition". -"Procedia Computer Science". -"Research in Developmental Disabilities". -"Digital Outcasts". -"Computers & Graphics". -"Entertainment Computing". -"Telematics and Informatics".
			In <i>Topic</i> : -"video game". -"computer science". -"game". -"virtual reality". -"digital outcast". -"disability". -"inter face". -"virtual world". -"computer game". -"kinect-based system". -"mobile phone". -"remote controller". -"serious game".
Web Of Science (ISI)	Sort by relevance		Without filters
INSPEC	Sort by relevance		Without filters
Scopus	Sort by relevance and writing search terms in an input that considers the fields <i>Article Title</i> , <i>Abstract</i> and <i>Keywords</i> in the search process		Without filters
Academic Premier	Search	Sort by relevance	Without filters
arXiv.org		By default	Without filters
Documat		By default	Without filters
e-libro		Sort by relevance	Selected "Informática", "Computers" and "Juegos" as <i>Topic</i>
ICYT		By default	Without filters
IGI Global InfoSci		Sort by relevance	The query results have been refined

Books		filtering through <i>Subjects</i> . First it chose “Engineering” and search process was repeated again selecting “Media and Communications”
INGeBOOK	By default	Without filters
MathSciNet (AMS)	By default	Without filters

As the search has been systematic for all kinds of sources (repeating the same process in databases and search engines), some publications have appeared on multiple occasions, either because they belong to a repository and, furthermore have been offered by one or several search engines, or because they have been published in several journals. However, it is preferable to find repeated components at the cost of a higher effort, even though there are duplicates and time has apparently been wasted, than to carry out the investigation in an excessively relaxed manner and leave relevant publications uncovered.

In essence, as soon as the results were obtained from each source, the same procedure was always done: the title, abstract and content of all the publications were evaluated to discover which should be stored (with all their relevant data [type of research performed, research questions resolved, type of publication, author/s, title, source, publication year, abstract, keywords, initial page, number of pages, title of conference or special issue (if necessary), ISSN/ISBN, DOI, link of complete reference, full text document, results/findings discovered, relevant references cited]) in a Refworks directory aimed at that purpose. That is, we identified those works directly or indirectly related to the field of study and which were included in the set of elements contemplated by the bibliographical tool mentioned. Once this was done with all the sources, a high number of components was obtained which could be used later after a more exhaustive revision (in which it is possible that some will be set aside or others may arise).

Thus, these initial phases of the bibliographic search process produced a publications base with 297 elements which conform, to a certain extent, an objective and scientific selection. The next step consisted of carefully revising each one of them to determine if the publication analyzed is indeed valid, in which case it can reveal to the researcher details of particular importance for the study underway, and shed some light on how to draw up the report on the state of the art.

3.4 Ensure the representativeness of the obtained resources

In the final stage of the process, the references obtained in previous steps were studied to guarantee a robust knowledge of the area under investigation. To achieve this, a series of quality criteria were used (date, relation to the field of study, approach used in the study, language of the document) to determine those studies of the initial set which should be ruled out (or taken into consideration) in the systematic review.

At this point, all the references gathered during the search process were revised, so that those not representative or not useful could be rejected. With this aim, an analysis was completed on every one of them, so that by reading the abstract and the conclusions, the search in the body of text for keywords and a quick scan of each

publication made it possible to determine its validity. If a reference bore no relation to the field of study upon reading the abstract and the conclusions, if it did not include in the full text the keywords (*accesibilidad/accessibility/accessible* and *videojuego/video game/mobile game*) or the approach was inadequate (lack of scientific rigour or absence of impartiality), it was not stored along with the rest. Therefore, thanks to the body of each publication and the set of metadata belonging to it, it was possible to exclude references that used the same terms the authors were looking for though with another meaning and publications which despite being related to the investigation were not of the required quality.

Concerning the criterion of the publication date, it was not necessary to filter, since the great majority of works analyzed were from the last decade (2004-2014).

Finally, out of the remaining elements, only those in which it was possible to obtain the full text of the publication and those written in Spanish or English were taken into consideration, since otherwise, the authors would have been unable to gain advantage from reading their contents.

Once the selection was made it was possible, to a certain extent, to ensure the representativeness of the results obtained, pending a rigorous reading in which some works could turn out to be insufficiently significant (in which case it would be ruled out later).

Among the works taken into consideration, a large number of elements directly related to the terms searched for could be found, as well as others indirectly related (interfaces, virtual worlds, etc.) and of possible use (they can be extrapolated to our case).

In all the steps related to resources' representativeness, the actions had been accomplished by several reviewers, and the disagreements were resolved by consensus.

3.4.1. Reading of the documents

Once this point was reached, the publications forming part of the collection of elements under consideration were read and studied and their content synthesized so as to be included in the state of art inside this document (in the section of foundations of accessibility and video games). That is, tasks corresponding to literature review and presentation of results were performed, with the help of a table of references (Appendix 1). The order of reading was hybrid, not corresponding to a sole criterion of decision, since the authors selected the works which (in their opinion) were most suited to the objective of the study and, during the review, references cited in these publications have been intermingled (giving priority to the most recurring as opposed to those with the least number of references).

The table of references included in Appendix 1, at the end of this paper, contains the publications under evaluation, including the main data (study ID, title, type of publication, source, link of complete reference, publication year, author/s, relevant references cited) and the enquiries reached for all of them, following an exhaustive review process.

It was decided to use this method because, with the resources mentioned, all the literature related to the issue in question can be synthesized and related in an orderly manner, and so the ideas and concepts necessary for the study can be more easily

condensed. In consequence, thanks to the process described here, a body of knowledge has been consolidated, which can serve as a basis for future research and help in a later project related to the field in question.

As the study corresponds to the perspective of Computer Science, works which approach the subject from other disciplines (social sciences, medicine, psychology, business studies, etc.) were not taken into account, although some of the publications included may be multidisciplinary and contain concepts typical of those fields. For this reason, it was decided to rule out, both in the prior steps and in the process of reading, many works which deal only with the effect of video games on violent attitudes in young people, the political connotations of the titles produced by this industry, data for purely statistical use, etc.

Before we start reading, some criteria were established to prioritize the selection of some publications over others, applying the method which is described ahead.

As the study is directly related to video games and accessibility (taking into consideration many different types of disability), it is imperative to make an intelligent choice of the first elements to be analyzed, since it is a multidisciplinary subject linked to all kinds of literature.

To be as precise as possible, we decided to order the references according to publication date in descending order (the most recent first) and to take those most representative:

- one on the issue of accessibility itself;
- another related to video games and the limitations of the elderly;
- a publication on video games and persons with motor disorders;
- another on the subject of this kind of software and autism;
- one relating to the blind and digital entertainment;
- another on video games and deaf people;
- etc.

The aim is simple: to cover in an initial stage an acceptable number of recent publications closely related to the area of study and go forward (with the analysis of the referenced works [new levels of review]) to reach a robust theoretical base which guarantees results. As each work, in turn, enables new publications to be manually discovered (revising the bibliography), the process becomes long and difficult, however it is necessary to complete it and reach a stage in which the perspective attained enables the authors to set out correctly and rigorously the state of the art.

This final aspect is fundamental, as the authors have the responsibility of deciding (based on the time available and the aim pursued) at what moment the initial revision of the literature is complete, and so advance to the following stage of the process (synthesis of the concepts assimilated during reading). In this case, after establishing three months as the maximum duration of the search for results phase, 297 references were obtained, a number which rose to 320 (4 of which were ruled out) after the manual search, 45 of these papers (which can be consulted in the table of Appendix 1) were finally studied in depth.

The systematic review performed (between the end of 2014 and the end of 2015) has involved three months of searches and another additional month to carry out the

analysis of the works retrieved and draw up the present document (a total of approximately 960 hours).

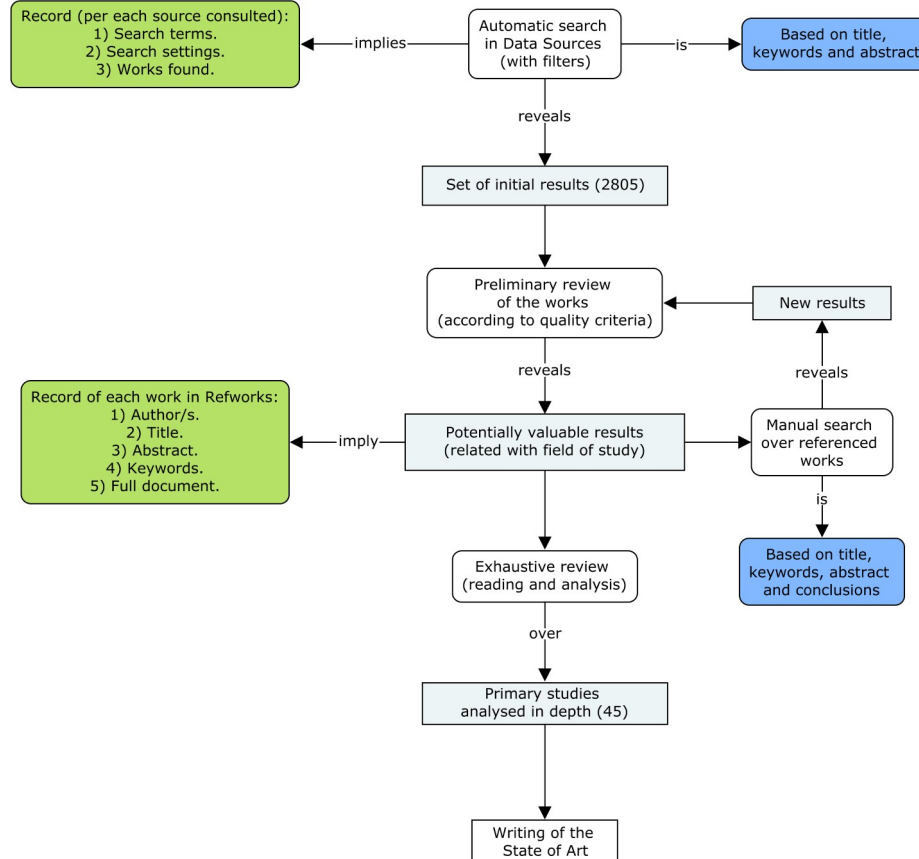


Fig. 4. Search process performed

During the reading of the references, a process of evaluation and narrative/conceptual synthesis (descriptive) was performed, summarizing the content of each work as from the ideas obtained in the table of references mentioned above.

Once the table had been elaborated (to support the process of reading of the publications concerned), it was possible to easily specify the knowledge acquired inside of the section of the state of art of accessibility in video games. The concepts discovered were interrelated in an orderly manner, citing the origin of each one.

4 Results analysis

After the creation of the state of the art, the authors completed an analysis of the results to obtain valuable quantitative information (general data of the performed search).

In this section, we specify which works were found, how many were taken into consideration and how many were ruled out. Moreover, to give information about them, a graph is provided with quantitative data by phases. Tables are included with the articles found, according to the source. Additionally, they are ordered by category (later detailed), and research activity is analyzed based on the year of publication.

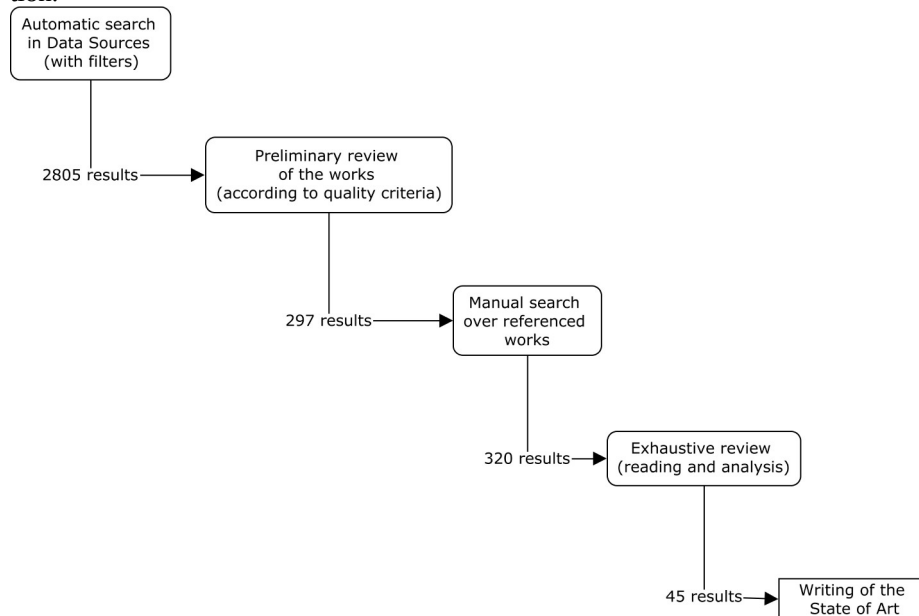


Fig. 5. Collection and selection of works during the search process

As can be appreciated in Figure 5, after applying the quality criteria described above to the initial results (obtained via automatic search with filters of inclusion/exclusion), and taking into consideration the relevant articles turned up by the manual search, we go from 2805 results obtained (962 with search terms in Spanish and 1843 with terms in English) to 320 (of which 4 were ruled out and 45 were studied in depth).

It is clear and testable (see Tables 2 and 3) that many more works related to the area of study were found using search terms in English than in Spanish.

Table 2. Identified articles addressed by consulted source (search terms in Spanish)

Data source	Number of reached results
Google Academics	290
BUAH	554
ACM Digital library	0
IEEE Xplore	0
SpringerLink	1
SpringerLink Books	0
Lecture notes in Computer Science (Springer-Link)	1

AENOR Más	39
Science Direct	13
Web Of Science (ISI)	0
INSPEC	0
Scopus	0
Academic Search Premier	0
arXiv.org	0
Documat	1
e-libro	62
ICYT	1
IGI Global InfoSci Books	0
INGeBOOK	0
MathSciNet (AMS)	0
ALL DATA SOURCES (TOTAL)	962

Table 3. Identified articles addressed by consulted source (search terms in English)

Data source	Number of reached results
Google Academics	400
BUAH	400
ACM Digital library	314
IEEE Xplore	68
SpringerLink	266
SpringerLink Books	0
Lecture notes in Computer Science (SpringerLink)	187
AENOR Más	0
Science Direct	32
Web Of Science (ISI)	44
INSPEC	12
Scopus	79
Academic Search Premier	6
arXiv.org	4
Documat	1
e-libro	27
ICYT	0
IGI Global InfoSci Books	3
INGeBOOK	0
MathSciNet (AMS)	0
ALL DATA SOURCES (TOTAL)	1843

The 45 resources selected are broken down according to the type of investigation carried out (see Table 5 and Figure 6), according to the research questions resolved (see Table 6 and Figure 7) and according to the type of disability addressed (see Table 7 and Figure 8). Additionally, data are provided about the type of publication those works correspond to (see Table 8).

Table 4. Research type facet (according to [50])

Class	Description
Validation Research	Techniques investigated are novel and have not yet been implemented in practice. Techniques used are for example experiments, i.e., work done in the lab.
Evaluation Research	Techniques are implemented in practice and an evaluation of the technique is conducted. That means, it is shown how the technique is implemented in practice (solution implementation) and what are the consequences of the implementation in terms of benefits and drawbacks (implementation evaluation). This also includes to identify problems in industry.
Solution Proposal	A solution for a problem is proposed, the solution can be either novel or a significant extension of an existing technique. The potential benefits and the applicability of the solution is shown by a small example or a good line of argumentation.
Philosophical Papers	These papers sketch a new way of looking at existing things by structuring the field in form of a taxonomy or conceptual framework.
Opinion Papers	These papers express the personal opinion of somebody whether a certain technique is good or bad, or how things should be done. They do not rely on related work and research methodologies.
Experience Papers	Experience papers explain what and how something has been done in practice. It has to be the personal experience of the author.

Table 5. Primary studies grouped according to the type of research performed

Type of research performed	Results (Study ID)
Validation Research	S06, S07, S23, S24, S37
Evaluation Research	S01, S02, S04, S05, S21, S22, S28, S30, S32, S33, S36, S38, S39, S40, S41, S42, S43, S44
Solution Proposal	S03, S08, S10, S11, S12, S13, S14, S17, S18, S20, S25, S26, S29, S31, S34, S35, S45
Philosophical Papers	S15, S19
Opinion Papers	S16
Experience Papers	S09, S27

Distribution of papers by type of research

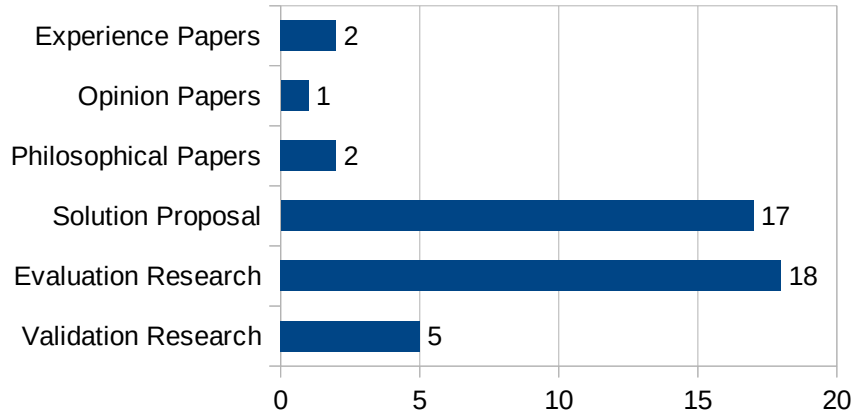


Fig. 6. Distribution of selected papers according to type of research

Evaluating the publications according to the kind of investigation [50], the works selected were generally of the type *Evaluation Research* or *Solution Proposal* (18 and 17 respectively), well above the categories *Validation Research* (5), *Philosophical Papers* (2), *Experience Papers* (2) and *Opinion Papers* (1).

Table 6. Primary studies grouped according to the research questions answered

Research question	Results (Study ID)
RQ1	S01, S02, S03, S06, S08, S09, S10, S11, S12, S13, S14, S16, S17, S19, S21, S22, S23, S24, S26, S28, S29, S31, S32, S33, S34, S35, S36, S37, S40
RQ2	S01, S02, S04, S05, S06, S08, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19, S20, S21, S22, S23, S24, S25, S26, S27, S28, S29, S30, S31, S32, S33, S34, S35, S36, S37, S40, S43, S44, S45
RQ3	None
RQ4	S01, S10, S14, S18, S19, S21, S22, S30, S32
RQ5	S10, S18, S19, S20, S22, S29, S33, S35
RQ6	S01, S02, S03, S04, S05, S06, S07, S10, S11, S15, S17, S19, S20, S21, S22, S23, S25, S26, S27, S31, S32, S35, S36, S37, S38, S39, S40, S42, S45

Distribution of papers by research questions

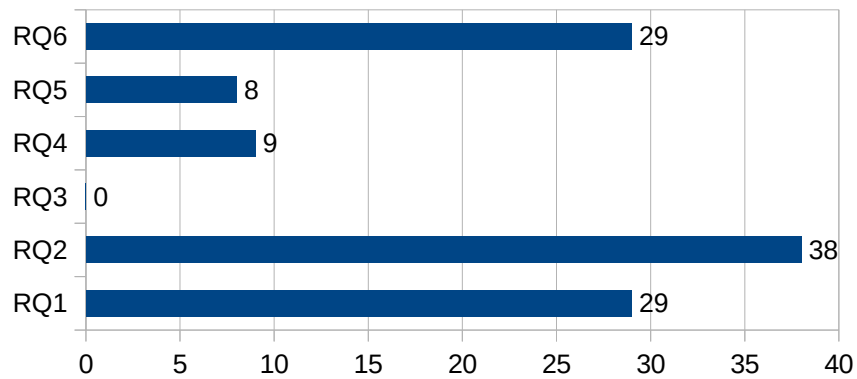


Fig. 7. Distribution of selected papers according to research questions

Regarding the questions used in the investigation, the works respond partially or entirely to most of them. The question with the greatest support is the second (38 studies), followed closely by questions 1 and 6 (both with 29 publications) and, finally, questions 4 and 5 (with 9 and 8, respectively). The only research question not resolved is the third one, which was so specific that it obtained no answer. Also, the study with identifier S41 offered no reply to any of the questions asked.

Table 7. Primary studies grouped according to the type of disability addressed

Type of disability addressed	Results (Study ID)
Visual	S01, S02, S03, S06, S09, S10, S16, S17, S18, S19, S20, S21, S22, S23, S24, S25, S26, S28, S29, S30, S31, S32, S33, S34, S35, S36, S44
Auditory	S02, S03, S07, S10, S16, S17, S18, S19, S20, S21, S22, S25, S26, S29, S30, S31, S32, S35, S36, S44
Motor	S01, S02, S03, S04, S08, S10, S11, S12, S13, S14, S18, S19, S20, S21, S22, S25, S26, S27, S29, S30, S31, S32, S35, S36, S37, S39, S40, S42, S43, S44
Cognitive	S03, S05, S10, S14, S17, S18, S19, S20, S21, S22, S25, S26, S29, S30, S31, S32, S35, S36, S42, S45

Distribution of papers by type of disability

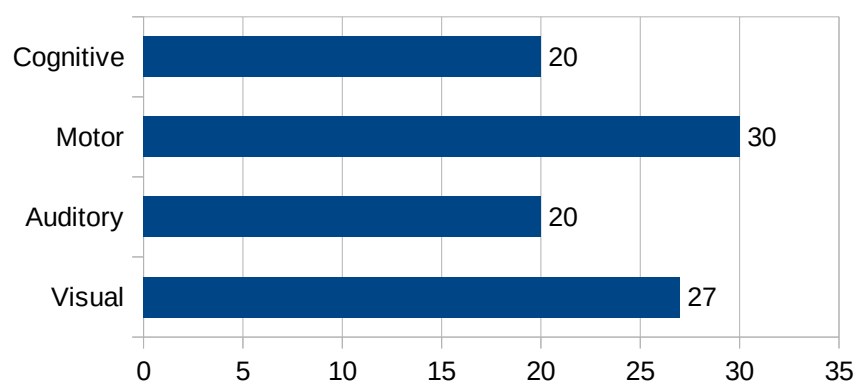


Fig.8. Distribution of selected papers according to type of disability

In relation to the type of disability, the works selected discuss one or several profiles. The most treated profile is motor impairment (30 studies), followed closely by visual impairment (27 studies) and, finally, auditory impairment and cognitive impairment (both with 20 studies). Only the studies S15, S38 and S41 do not mention any type of disability.

Table 8. Primary studies grouped according to the type of publication

Type of publication	Number of results	Percentage
Journal	20	44,5%
Conference	22	48,9%
Web	1	2,2%
Report	2	4,5%

Depending on the type of publication, there are a higher number of works in the class *Conference* (48,9% of the total selected) and *Journal* (44,5%) compared to *Web* (2,2%) and *Report* (4,5%), whose number is residual.

It is also relevant to test how research activity in this field has varied with time, for which reason Table 9 and Figure 9 have been drawn up. These show the figures corresponding to the number of works, organized by year and kind of publication.

Table 9. Primary studies grouped according to their publication years

Year/Type of public.	Journal	Conference	Web	Report
2004 (3 works)	1 (33,3%)	1 (33,3%)	0 (0%)	1 (33,3%)
2005 (1 work)	1 (100%)	0 (0%)	0 (0%)	0 (0%)
2006 (0 works)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
2007 (1 work)	1 (100%)	0 (0%)	0 (0%)	0 (0%)

2008 (4 works)	2 (50%)	2 (50%)	0 (0%)	0 (0%)
2009 (1 work)	0 (0%)	1 (100%)	0 (0%)	0 (0%)
2010 (1 work)	0 (0%)	1 (100%)	0 (0%)	0 (0%)
2011 (6 works)	2 (33,3%)	4 (66,7%)	0 (0%)	0 (0%)
2012 (9 works)	5 (55,6%)	2 (22,2%)	1 (11,1%)	1 (11,1%)
2013 (13 works)	3 (23,1%)	10 (76,9%)	0 (0%)	0 (0%)
2014 (6 works)	5 (83,3%)	1 (16,7%)	0 (0%)	0 (0%)

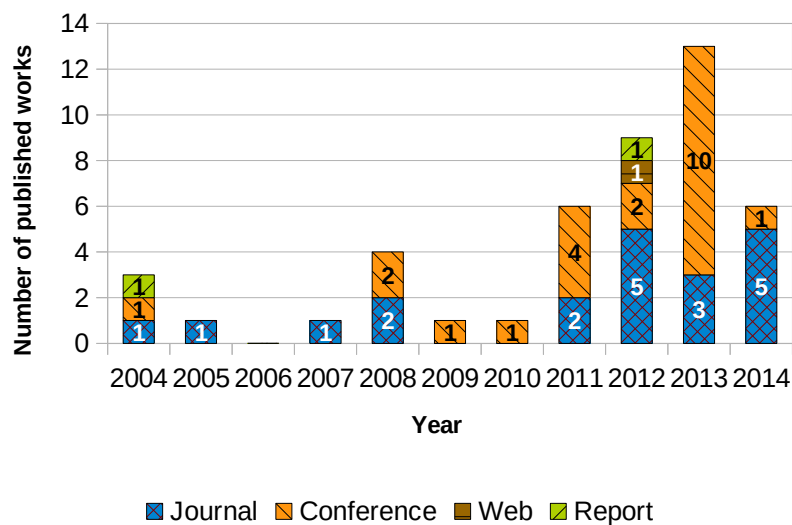


Fig. 9. Distribution of selected primary studies by their publication years

Analysing the data, it can be concluded that research activity in the past decade has increased significantly, since the number of publications goes up from an average of 1,57 in the first years (2004 to 2010) to an average of 8,5 works per year in the final stage of the period under consideration in the SLR (2011 to 2014). With a more exhaustive analysis, it is possible to find that the worst year was 2006 (in which there are none considered sufficiently relevant using the search criteria) and the best was 2013 (13 elements). It can also be observed that the years 2005, 2007, 2009 and 2010 only have one publication and that, after a notable increase in 2011 (6 works), 2012 (9 works) and 2013 (13 works), in the year 2014 the number decreased in comparison with the previous year (6 works).

Following this general search data, the elements of interest related to accessibility in video games will be outlined.

5 Discussion of the results

Taking into account the information provided so far, the authors proposed a discussion based on the content and the way it was obtained.

5.1 Main findings

None of the studied initiatives can guarantee universally accessible video games:

1. Approaches that involve particular interfaces and custom developments may lead to a lack of quality in the generated/adapted video games and the segregation of disabled players [22];
2. The frameworks often depend on the use of specific technologies. This dependence hinders accessibility, since it necessarily involves the use of elements that can be beyond the control of the developer (they belongs to third parties) and limit the available options;
3. The guidelines, techniques, strategies, etc. that facilitate the development of accessible video games are ignored by many developers (due to ignorance, lack of comprehension, impossibility of application, etc.) [21, 52].

Table 10. Research questions answered by the primary studies

Primary Study/Research question	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6
S01 (4 RQ)	X	X		X		X
S02 (3 RQ)	X	X				X
S03 (2 RQ)	X					X
S04 (2 RQ)		X				X
S05 (2 RQ)		X				X
S06 (3 RQ)	X	X				X
S07 (1 RQ)						X
S08 (2 RQ)	X	X				
S09 (1 RQ)	X					
S10 (5 RQ)	X	X		X	X	X
S11 (3 RQ)	X	X				X
S12 (2 RQ)	X	X				
S13 (2 RQ)	X	X				
S14 (3 RQ)	X	X		X		
S15 (2 RQ)		X				X
S16 (2 RQ)	X	X				
S17 (3 RQ)	X	X				X
S18 (3 RQ)		X		X	X	
S19 (5 RQ)	X	X		X	X	X
S20 (3 RQ)		X			X	X
S21 (4 RQ)	X	X		X		X
S22 (5 RQ)	X	X		X	X	X
S23 (3 RQ)	X	X				X
S24 (2 RQ)	X	X				
S25 (2 RQ)		X				X
S26 (3 RQ)	X	X				X
S27 (2 RQ)		X				X
S28 (2 RQ)	X	X				
S29 (3 RQ)	X	X			X	
S30 (2 RQ)		X		X		

S31 (3 RQ)	X	X			X
S32 (4 RQ)	X	X	X		X
S33 (3 RQ)	X	X		X	
S34 (2 RQ)	X	X			
S35 (4 RQ)	X	X		X	X
S36 (3 RQ)	X	X			X
S37 (3 RQ)	X	X			X
S38 (1 RQ)					X
S39 (1 RQ)					X
S40 (3 RQ)	X	X			X
S41 (0 RQ)					
S42 (1 RQ)					X
S43 (1 RQ)		X			
S44 (1 RQ)		X			
S45 (2 RQ)		X			X

The most valuable studies are those with the identifiers S10, S19 and S22 since they provide a clear contribution to five different research questions. Just after (with partial or complete response to 4 different questions), the studies S01, S21, S32 and S35 are also relevant. The remaining works answer to a lower number of issues (15 to 3 RQ, 15 to 2 RQ and 7 to 1 RQ) except the S41, which poses no progress in this area (it does not respond to any RQ).

At this point it is important to answer the Research Questions:

- About RQ1, “Are video games being developed today truly accessible?”, the answer is not;
- In relation to RQ2, the researchers/developers have proposed solutions in order to increase the accessibility of the video games being produced, however they are not enough;
- There is no answer for RQ3 because no study provides further insights about this question. However, the authors could argue that a specific development methodology arising from the adaptations and/or modifications of existing solutions could have a notable impact on the level of accessibility of the video games;
- Regarding RQ4, the developers of video games do not appreciate the proposals and improvements previously suggested in terms of accessibility (do not apply them);
- About RQ5, it can be said that the pursuit of universal accessibility of video games is a difficult task and, usually (mentioned in many studies), is not a realistic, achievable and/or profitable aim (consequence of cost or ignorance);
- In relation to RQ6, there is no doubt that video games provide benefits for people apart from their entertainment value (learning process and rehabilitation therapies).

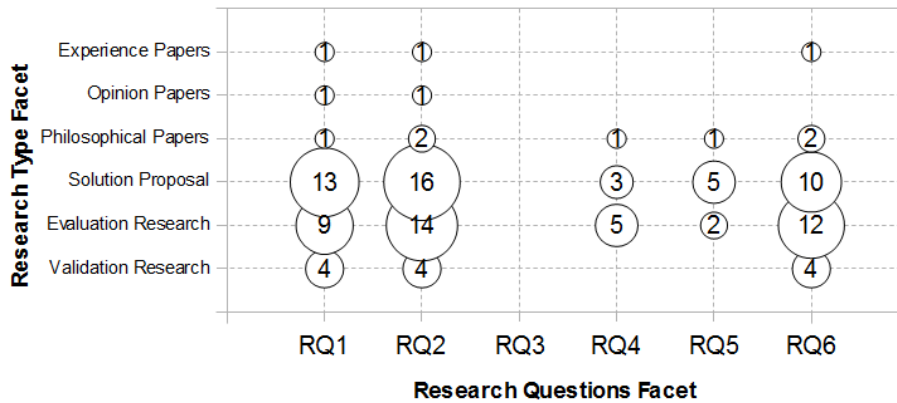


Fig. 10. Visualization of a systematic map in the form of a bubble plot

Finally, reviewing the content of Figure 10, it is possible to comprehend the relation between the research type of the works studied and the research questions. The breakdown of questions answered (all except the RQ3) reveals that *solution proposal* is the type that brings more information (with answers in 47 works [13 to RQ1, 16 to RQ2, 3 to RQ4, 5 to RQ5 and 10 to RQ6]), followed by *evaluation research* class (with answers in 42 works [9 to RQ1, 14 to RQ2, 5 to RQ4, 2 to RQ5 and 12 to RQ6]). Just after though very far, *validation research* provides answers in 12 works (4 to RQ1, 4 to RQ2 and 4 to RQ6), *philosophical papers* contributes with answers in 7 works (1 to RQ1, 2 to RQ2, 1 to RQ4, 1 to RQ5 and 2 to RQ6), *experience papers* do the same with 3 works (1 to RQ1, 1 to RQ2 and 1 to RQ6) and *opinion papers* answers in 2 works (1 to RQ1 and 1 to RQ2).

5.2 Limitations of the literature review

It is advisable to evaluate the review that was executed, to determine the accuracy attained in the search, the validity of the articles analyzed, the possible lack of precision in the extraction of data and digressions committed concerning the procedures of SLR. In this way, the skewing of the process and its results can be discerned, and the weak points of the review identified.

The kinds of publications considered, as could be observed in previous sections, are varied. As each type of publication has a particular maximum extension, different for long papers than for conference proceedings (for example), the level of specificity/precision which can be attained differs considerably. So, some works gave the author less evidence or revealed conclusions with a smaller degree of precision.

Furthermore, some of the works reviewed are multidisciplinary, and because they follow a mixed approach (for example, Computer Science and Medicine) the extraction of data was complicated. For this reason, it is possible that some inaccuracies have arisen during the process of data collection (the language used differs from that used by a specialist in Software Engineering).

The research questions were drawn up bearing in mind the usual recommendations (population, intervention, comparison, outcomes, context) although in a somewhat unorthodox manner.

Since this is a Systematic Mapping Study, both the questions formulated and the terms searched for are very general, with the aim of establishing a broad view related to the field that does not rule out any branch that might be relevant. This way of proceeding differs from the usual one in SLR, however makes sense bearing in mind that it is a particular kind of review (SMS) with some unusual characteristics.

Considering all the previous comments, we may argue that the completed search has sufficient quality to guarantee the necessary rigor, however, it could have been carried out more precisely.

6 Conclusions

After analyzing all the data presented, the conclusion is that we do not have to pursue remedies to mitigate the lack of accessibility of current video games. Instead, it is important to provide solutions to reverse the situation radically, with principles which ensure that the generated products meet specific requirements (usable and accessible video games for any player).

A solution in line with this philosophy could be an integral methodology that considers accessibility guidelines, techniques, strategies, etc. for all phases of video game development. If it is systematically defined, combining progress already made by others with new ideas (such as the opinions of experts and the people with disability, the existing impairments and the possible platforms), it could serve as a model for future developments.

As a future line of work, we propose to formally define and verify the validity of a methodology with these characteristics, which, if used, could increase the level of accessibility of video games.

Additionally, regarding the drawbacks and omissions of analyzed works, we can point to further or new research in this domain, considering insights such as the type of research to be performed, the research questions answered and the type of disability. Considering the limited number of studies in Validation Research, Philosophical Papers, Experience Papers and Opinion Papers categories (as shown in Figure 6 and Figure 10), it is necessary to contribute to this field of study with more works on these lines. Regarding the research questions answered, RQ3 is the only one not addressed by literature. It cannot be answered until a methodology which considers the features mentioned above is developed. In relation to the existing types of disability, there is a lack of studies in auditory or cognitive impairments compared with visual and motor disabilities. Additional research on video games and these unattended profiles is strongly recommended.

References

1. Ampatzoglou, A., & Stamelos, I.: Software Engineering Research for Computer Games: A Systematic Review. *Information and Software Technology*, 52 (2010) 888-901
2. Anam, A. I., & Yeasin, M.: Accessibility in Smartphone Applications: What do we Learn from Reviews? (2013) 35:1-35:2
3. Badia, A., García, O., Labrador, E. et al.: Experiencia De Usuario En Los Serious Games Para Personas Con Necesidades De Accesibilidad. *Buenas prácticas de accesibilidad en videojuegos*, (2012) 60-67
4. Barlet, M. C., & Spohn, S. D.: *A Practical Guide to Game Accessibility*. (2012)
5. Barnett, P., & Humphreys, S.: *Game Accessibility Guidelines*. 2014
6. Bierre, K., Hinn, M., Martin, T. et al.: *Accessibility in Games: Motivations and Approaches*. (2004)
7. Boutsika, E.: Kinect in Education: A Proposal for Children with Autism. *Procedia Computer Science*, 27 (2014) 123-129
8. Carrington, P., Hurst, A., Kane, S. K.: *Wearables and Chairables: Inclusive Design of Mobile Input and Output Techniques for Power Wheelchair Users*. (2014) 3103-3112
9. Crespo, Á G., & Tejedor, Á G.: Análisis De Videojuegos Comerciales Y Sus Lagunas En La Accesibilidad Para Las Personas Con Discapacidad Sensorial. *Buenas prácticas de accesibilidad en videojuegos*, (2012) 48-52
10. Díez Alegre, M. I.: La Accesibilidad En Los Videojuegos: Una Asignatura Pendiente. *Revista Española de Discapacidad*, 1 (2013) 155-158
11. Fernández, A.: La Importancia De Los Idiomas En La Mejora De La Accesibilidad En Videojuegos Para Personas Mayores. *Buenas prácticas de accesibilidad en videojuegos*, (2012) 35-38
12. Garber, L.: *Game Accessibility: Enabling Everyone to Play*. *Computer*, 46 (2013) 14-18
13. Gerling, K. M.: *Motion-Based Game Interaction for Older Adults*. *SIGACCESS Access.Comput.*, (2014) 27-30
14. Gerling, K. M., Dergousoff, K. K., Mandryk, R. L.: *Is Movement Better?: Comparing Sedentary and Motion-Based Game Controls for Older Adults*. (2013) 133-140
15. Gerling, K. M., Kalyn, M. R., Mandryk, R. L.: *KINECTwheels: Wheelchair-Accessible Motion-Based Game Interaction*. (2013) 3055-3058
16. Gerling, K., Livingston, I., Nacke, L. et al.: *Full-Body Motion-Based Game Interaction for Older Adults*. (2012) 1873-1882
17. Gerling, K. M., Mandryk, R. L., Kalyn, M. R.: *Wheelchair-Based Game Design for Older Adults*. (2013) 27:1-27:8
18. Gil Juárez, A., & Vida Mombiela, T.: *Los videojuegos*. Editorial UOC (2007)
19. Gómez, I. M., Molina, A. J., Cabrera, R. et al.: *The Possibilities of Kinect as an Access Device for People with Cerebral Palsy*. 8548 (2014) 252-255
20. González, C., & Vela, J.: *Propuesta De Evaluación De Videojuegos Accesibles*. *Buenas prácticas de accesibilidad en videojuegos*, (2012) 53-59
21. Grammenos, D.: *Game Over: Learning by Dying*. (2008) 1443-1452
22. Grammenos, D., Savidis, A., Stephanidis, C.: *Unified Design of Universally Accessible Games*. 4556 (2007) 607-616
23. Hiraga, R., & Hansen, K. F.: *Sound Preferences of Persons with Hearing Loss Playing an Audio-Based Computer Game*. (2013) 25-30

24. Karray, F., Alemzadeh, M., Saleh, J. A. et al.: Human-Computer Interaction: Overview on State of the Art. *INTERNATIONAL JOURNAL ON SMART SENSING AND INTELLIGENT SYSTEMS*, 1 (2008) 137-159
25. Kim, J., & Ricaurte, J.: TapBeats: Accessible and Mobile Casual Gaming. (2011) 285-286
26. Kim, Y., Sutreja, N., Froehlich, J. et al.: Surveying the Accessibility of Touchscreen Games for Persons with Motor Impairments: A Preliminary Analysis. (2013) 68:1-68:2
27. Kitchenham, B. A., Budgen, D., Pearl Brereton, O.: Using Mapping Studies as the Basis for further Research – A Participant-Observer Case Study. *Information and Software Technology*, 53 (2011) 638-651
28. Kitchenham, B., & Charters, S.: Guidelines for performing systematic literature reviews in software engineering. In: Anonymous Technical report, Ver. 2.3 EBSE Technical Report. EBSE (2007)
29. Kitchenham, B., Pretorius, R., Budgen, D. et al.: Systematic Literature Reviews in Software Engineering – A Tertiary Study. *Information and Software Technology*, 52 (2010) 792-805
30. Kurschl, W., Augstein, M., Stitz, H.: Adaptive User Interfaces on Tablets to Support People with Disabilities. (2012) 91-94
31. LeBlanc A. G., Chaput J., McFarlane A., Colley R.C., Thivel D., Biddle S.J.H., Maddison R., Leatherdale S.T., Tremblay M.S.: Active video games and health indicators in children and youth: A systematic review. *PLOS ONE* 8, e65351 (2013)
32. Leigh, S.: eyeCan: Affordable and Versatile Gaze Interaction. (2013) 79-80
33. Liberati A., Altman D.G., Tetzlaff J., Mulrow C., Gøtzsche P.C., Ioannidis J.P.A., Clarke M., Devereaux P.J., Kleijnen J., Moher D.: The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *PLOS Medicine* 6, e1000100 (2009)
34. Mangiron, C., & Orero, P.: ¿ Videojuegos Para Todos? Panorama Actual De La Accesibilidad En Videojuegos. *Buenas prácticas de accesibilidad en videojuegos*, (2012) 23-28
35. Miesenberger, K., Ossmann, R., Archambault, D. et al.: More than just a Game: Accessibility in Computer Games. 5298 (2008) 247-260
36. Moher D., Liberati A., Tetzlaff J., Altman D.G., The P.G.: Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLOS Medicine* 6, e1000097 (2009)
37. Morelli, T., Foley, J., Folmer, E.: Vi-Bowling: A Tactile Spatial Exergame for Individuals with Visual Impairments. (2010) 179-186
38. Morelli, T., & Folmer, E.: Real-Time Sensory Substitution to Enable Players Who are Blind to Play Video Games using Whole Body Gestures. *Entertainment Computing*, 5 (2014) 83-90
39. Mueller, F. ', Edge, D., Vetere, F. et al.: Designing Sports: A Framework for Exertion Games. (2011) 2651-2660
40. Plaza, I., Martín, L., Martín, S. et al.: Mobile applications in an aging society: Status and trends. *Journal of Systems and Software*, 84 (2011) 1977-1988
41. Poor, G. M., Leventhal, L. M., Kelley, S. et al.: Thought Cubes: Exploring the use of an Inexpensive Brain-Computer Interface on a Mental Rotation Task. (2011) 291-292
42. Porter, J. R.: Understanding and Addressing Real-World Accessibility Issues in Mainstream Video Games. *SIGACCESS Access.Comput.*, (2014) 42-45
43. Porter, J. R., & Kientz, J. A.: An Empirical Study of Issues and Barriers to Mainstream Video Game Accessibility. (2013) 3:1-3:8

44. Roy, A., Soni, Y., Dubey, S.: Enhancing Effectiveness of Motor Rehabilitation using Kinect Motion Sensing Technology. Global Humanitarian Technology Conference: South Asia Satellite (GHTC-SAS), 2013 IEEE, (2013) 298-304
45. Sehaba, K., Estrailier, P., Lambert, D.: Interactive Educational Games for Autistic Children with Agent-Based System. 3711 (2005) 422-432
46. Suma, E. A., Krum, D. M., Lange, B. et al.: Adapting User Interfaces for Gestural Interaction with the Flexible Action and Articulated Skeleton Toolkit. *Comput. Graph.*, 37 (2013) 193-201
47. Vickers, S., Istance, H., Heron, M. J.: Accessible Gaming for People with Physical and Cognitive Disabilities: A Framework for Dynamic Adaptation. (2013) 19-24
48. Villaroman, N., Rowe, D., Swan, B.: Teaching Natural User Interaction using OpenNI and the Microsoft Kinect Sensor. (2011) 227-232
49. Westin, T.: Game Accessibility Case Study: Terraformers—a Real-Time 3D Graphic Game. (2004) 95-100
50. Wieringa, R., Maiden, N., Mead, N. et al.: Requirements Engineering Paper Classification and Evaluation Criteria: A Proposal and a Discussion. *Requirements Engineering*, 11 (2006) 102-107
51. Yuan, B., & Folmer, E.: Blind Hero: Enabling Guitar Hero for the Visually Impaired. (2008) 169-176
52. Yuan, B., Folmer, E., Harris, F., Jr.: Game Accessibility: A Survey. *Universal Access in the Information Society*, 10 (2011) 81-100

Appendix 1: Table of references

In this section additional information is attached, which may be of use for understanding the process of bibliographic review described in this paper.

The information given is a reduced version (without the columns of subjective content) of the references table generated in that process, in which the data of the works comprehensively reviewed can be found. In the table, the publications are situated according to the order in which they were read.

Table 1. Studies analyzed in depth during SLR

Study ID	Title	Type of publication	Source	Link of complete reference	Publication year	Author/s	Relevant references cited (ID)
S01	Understanding and Addressing Real-world Accessibility Issues in Mainstream Video Games	Journal	ACM SIGACCESS Accessibility and Computing (ACM New York, NY, USA)	http://doi.acm.org/10.1145/2591357	2014	Porter, J. R.	S30, S31, S23, S32, S33, S21, S24
S02	La accesibilidad en los videojuegos: una asignatura pendiente	Journal	Revista Española de Discapacidad (RIBERDIS)	http://hdl.handle.net/11181/4018	2013	Díez, M. I.	S35, S25, S22
S03	Motion-based Game Interaction for Older Adults	Journal	ACM SIGACCESS Accessibility and Computing (ACM New York, NY,	http://doi.acm.org/10.1145/2591357	2014	Gerling, K. M.	S36, S26, S37, S38

S04	The Possibilities of Kinect as an Access Device for People with Cerebral Palsy	Journal	USA) Computers Helping People with Special Needs (Lecture Notes in Computer Science, Springer International Publishing)	http://dx.doi.org/10.1007/978-3-319-08599-9_38	2014	Gómez, I. M.; Molina, A. J.; Cabrera, R.; Valenzuela, D.; Garrido, M.	S39, S40
S05	Kinect in Education: A Proposal for Children with Autism	Journal	5th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion, DSAI 2013 (Procedia Computer Science [Elsevier], ScienceDirect)	http://dx.doi.org/10.1016/j.procs.2014.02.015	2014	Boutsika, E.	S41, S42, S44, S45
S06	Real-time sensory substitution to enable players who are blind to play video games using whole body gestures	Journal	Entertainment Computing (ScienceDirect [Elsevier])	http://dx.doi.org/10.1016/j.entcom.2013.08.003	2014	Morelli, T.; Folmer, E.	S23, S21, S24
S07	Sound Preferences of Per-	Conference	Proceedings of the 3rd ACM In-	http://doi.acm.org/	2013	Hiraga, R.; Hansen, K. F.	none

	sons with Hearing Loss Playing an Audio-based Computer Game		ternational Workshop on Interactive Multimedia on Mobile & Portable Devices (ACM New York, NY, USA)	10.1145/2505483 .2505489			
S08	Wearables and Chairables: Inclusive Design of Mobile Input and Output Techniques for Power Wheelchair Users	Conference	Proceedings of the 32Nd Annual ACM Conference on Human Factors in Computing Systems (ACM New York, NY, USA)	http://doi.acm.org/10.1145/2556288.2557237	2014	Carrington, P.; Hurst, A.; Kane, S. K.	none
S09	Accessibility in Smartphone Applications: What Do We Learn from Reviews?	Conference	Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility (ACM New York, NY, USA)	http://doi.acm.org/10.1145/2513383.2513421	2013	Anam, A. I.; Yeasin, M.	none
S10	Game Accessibility: Enabling Everyone to Play	Journal	Computer (IEEE Xplore)	http://dx.doi.org/10.1109/MC.2013.206	2013	Garber, L.	none
S11	KINECT-wheels: Wheelchair-accessible	Conference	CHI '13 Extended Abstracts on Human Factors	http://doi.acm.org/10.1145/2468356	2013	Gerling, K. M.; Kalyn, M. R.; Mandryk, R. L.	S26

	Motion-based Game Interaction		in Computing Systems (ACM New York, NY, USA)	.2479609			
S12	Surveying the Accessibility of Touchscreen Games for Persons with Motor Impairments: A Preliminary Analysis	Conference	Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility (ACM New York, NY, USA)	http://doi.acm.org/10.1145/2513383.2513416	2013	Kim, Y.; Sutreja, N.; Froehlich, J.; Findlater, L.	S21
S13	eyeCan: Affordable and Versatile Gaze Interaction	Conference	Proceedings of the Adjunct Publication of the 26th Annual ACM Symposium on User Interface Software and Technology (ACM New York, NY, USA)	http://doi.acm.org/10.1145/2508468.2514719	2013	Leigh, S.	S27
S14	Accessible Gaming for People with Physical and Cognitive Disabilities: A Framework for Dynamic Ad-	Conference	CHI '13 Extended Abstracts on Human Factors in Computing Systems (ACM New York, NY, USA)	http://doi.acm.org/10.1145/2468356.2468361	2013	Vickers, S.; H.; Heron, M. J.	S27, S25, S21

S15	aptation Experiencia de Usuario en los Serious Games para personas con necesidades de Accesibilidad	Journal	Buenas prácticas de accesibilidad en videojuegos (IMSERSO) (Google Academics)	http://www.ceapat.es/groups/imserso/documents/binario/accesvideojuegos.pdf#page=60	2012	Badia, A.; García, O.; Labrador, E.; Pifarré, M.; Villegas, E.	none
S16	Análisis de videojuegos comerciales y sus lagunas en la accesibilidad para las personas con discapacidad sensorial	Journal	Buenas prácticas de accesibilidad en videojuegos (IMSERSO) (Google Academics)	http://www.ceapat.es/groups/imserso/documents/binario/accesvideojuegos.pdf#page=48	2012	Crespo, Á. G.; Tejedor, Á. G.	none
S17	La importancia de los idiomas en la mejora de la accesibilidad en videojuegos para personas mayores	Journal	Buenas prácticas de accesibilidad en videojuegos (IMSERSO) (Google Academics)	http://www.imserso.es/groups/imserso/documents/binario/accesvideojuegos.pdf#page=35	2012	Fernández, A.	none
S18	Propuesta de evaluación de videojuegos accesibles	Journal	Buenas prácticas de accesibilidad en videojuegos (IMSERSO) (Google Academics)	http://ciudadesamigables.imserso.es/InterPresent1/groups/imserso/documents/binario/accesvideojuegos.pdf#page=53	2012	González, C.; Vela, J.	none

S19	¿Videojuegos para todos? Panorama actual de la accesibilidad en videojuegos	Journal	Buenas prácticas de accesibilidad en videojuegos (IMSERSO) (Google Academics)	http://www.car-m.es/ctra/cen-doc/haddock/16164.pdf#page=23	2012	Mangiron, C.; Orero, P.	S22, S21
S20	Adaptive User Interfaces on Tablets to Support People with Disabilities	Conference	Mensch & Computer Workshopband (Google Academics)	http://www.lifetool.at/fileadmin/user_upload/03_F_und_E/ Publikationen/ 2012_Paper_Kurschl.pdf#page=1 &zoom=auto,-244,842	2012	Kurschl, W.; Augstein, M.; Stitz, H.	S22, S21
S21	Game accessibility: a survey	Journal	Universal Access in the Information Society (Springer-Verlag)	http://dx.doi.org/10.1007/s10209-010-0189-5	2011	Yuan, B.; Folmer, E.; Harris, F. C. Jr.	S30, S22, S45, S33, S24
S22	Accesibility in games: motivations and approaches	Report	International Game Developers Association (IGDA)	http://archives.ig-da.org/accessibility/IGDA_Accessibility_WhitePaper.pdf	2004	Bierre, K.; Hinn, M.; Martin, T.; McIntosh, M.; Snider, T.; Stone, K.; Westin, T.	none
S23	Vi-bowling: A Tactile Spatial Exergame for Individuals with Visual Impair-	Conference	Proceedings of the 12th International ACM SIGACCESS Conference on	http://doi.acm.org/10.1145/1878803.1878836	2010	Morelli, T.; Foley, J.; Folmer, E.	S24, S21

	ments		Computers and Accessibility (ACM New York, NY, USA)				
S24	Blind Hero: Enabling Guitar Hero for the Visually Impaired	Conference	Proceedings of the 10th International ACM SIGACCESS Conference on Computers and Accessibility (ACM New York, NY, USA)	http://doi.acm.org/10.1145/1414471.1414503	2008	Yuan, B.; Folmer, E.	none
S25	Game accessibility guidelines	Web	Internet (accessed in 29/07/2014)	http://www.gameaccessibility-guidelines.com	2012	Various	none
S26	Full-body Motion-based Game Interaction for Older Adults	Conference	Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (ACM New York, NY, USA)	http://doi.acm.org/10.1145/2207676.2208324	2012	Gerling, K.; Livingston, I.; Nacke, L.; Mandryk, R.	S38
S27	Gaze-based Interaction with Massively Multiplayer On-line Games	Conference	CHI '09 Extended Abstracts on Human Factors in Computing Systems (ACM New York, NY, USA)	http://doi.acm.org/10.1145/1520340.1520670	2009	Istance, H.; Vickers, S.; Hyrskykari, A.	none

S28	Adapting main-stream multi-media games for severely visually impaired children	Journal	Eurosis, Ghent (Google Aca-demics)	http://www.resi-aw.fr/sites/default/files/publications-recherche/icos2004.pdf	2004	Archambault, D.; Baud, A.; Lerebourg, S.; Olivier, D.	none
S29	Unified Design of Universally Accessible Games	Journal	Universal Access in Human-Computer Interaction. Applications and Services (Lecture Notes in Computer Science, Springer Berlin Heidelberg)	http://dx.doi.org/10.1007/978-3-540-73283-9_67	2007	Grammenos, D.; Savidis, A.; Stephanidis, C.	none
S30	Game over: Learning by Dying	Conference	Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (ACM New York, NY, USA)	http://doi.acm.org/10.1145/1357054.1357281	2008	Grammenos, D.	S29, S22
S31	More Than Just a Game: Accessibility in Computer Games	Journal	HCI and Usability for Education and Work (Lecture Notes in Computer Science, Springer Berlin Heidelberg)	http://dx.doi.org/10.1007/978-3-540-89350-9_18	2008	Miesenberger, K.; Ossmann, R.; Archambault, D.; Searle, G.; Holzinger, A.	S28

S32	An Empirical Study of Issues and Barriers to Mainstream Video Game Accessibility	Conference	Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility (ACM New York, NY, USA)	http://doi.acm.org/10.1145/2513383.2513444	2013	Porter, J. R.; Kientz, J. A.	S22, S25, S30, S35, S31, S23, S33, S21, S24
S33	Game accessibility case study: Terraformers—a real-time 3D graphic game	Conference	Proc. 5th Intl Conf. Disability, Virtual Reality & Assoc. Tech (Google Academics)	http://www.icdv-rat.rdg.ac.uk/2004/papers/S03_N3_Westin_ICDV-RAT2004.pdf	2004	Westin, T.	none
S34	TapBeats: Accessible and Mobile Casual Gaming	Conference	The Proceedings of the 13th International ACM SIGACCESS Conference on Computers and Accessibility (ACM New York, NY, USA)	http://doi.acm.org/10.1145/2049536.2049609	2011	Kim, J.; Ricaurte, J.	S24
S35	A practical guide to game accessibility	Report	Internet (accessed in 29/07/2014)	http://www.includification.com/AbleGamers_Includification.pdf	2012	Barlet, M. C.; Spohn, S. D.	none
S36	Is Movement Better?: Comparing Sedent-	Conference	Proceedings of Graphics Interface 2013 (ACM	http://dl.acm.org/citation.cfm?	2013	Gerling, K. M.; Dergousoff, K. K.; Mandryk, R. L.	S26

	ary and Motion-based Game Controls for Older Adults		New York, NY, USA)	id=2532129.253 2153			
S37	Wheelchair-based Game Design for Older Adults	Conference	Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility (ACM New York, NY, USA)	http://doi.acm.org/10.1145/2513383.2513436	2013	Gerling, K. M.; Man-dryk, R. L.; Kalyn, M. R.	S11, S26
S38	Designing Sports: A Framework for Exertion Games	Conference	Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (ACM New York, NY, USA)	http://doi.acm.org/10.1145/1978942.1979330	2011	Mueller, F. 'Floyd'; Edge, D.; Vetere, F.; Gibbs, M. R.; Agamanolis, S.; Bongers, B.; Sheridan, J. G.	none
S39	Enhancing effectiveness of motor rehabilitation using kinect motion sensing technology	Conference	Global Humanitarian Technology Conference: South Asia Satellite (GHTC-SAS), 2013 IEEE (IEEE Xplore)	http://dx.doi.org/10.1109/GHTC-SAS.2013.6629934	2013	Roy, AK.; Soni, Y.; Dubey, S.	none
S40	Adapting user interfaces for gestural interac-	Journal	Computers & Graphics (ScienceDirect [El-	http://dx.doi.org/10.1016/	2013	Suma, E. A.; Krum, D. M.; Lange, B.; Koenig, S.; Rizzo, A.; Bolas,	none

	tion with the flexible action and articulated skeleton toolkit		sevier])	j.cag.2012.11.004		M.
S41	Kinect Identity: Technology and Experience	Journal	Computer (IEEE Xplore)	http://dx.doi.org/10.1109/MC.2011.114	2011	Leyvand, T.; Meekhof, C.; Yi-Chen Wei; Jian Sun; Baining Guo
S42	Teaching Natural User Interaction Using OpenNI and the Microsoft Kinect Sensor	Conference	Proceedings of the 2011 Conference on Information Technology Education (ACM New York, NY, USA)	http://doi.acm.org/10.1145/2047594.2047654	2011	Villaroman, N.; Rowe, D.; Swan, B.
S43	Thought Cubes: Exploring the Use of an Inexpensive Brain-computer Interface on a Mental Rotation Task	Conference	The Proceedings of the 13th International ACM SIGACCESS Conference on Computers and Accessibility (ACM New York, NY, USA)	http://doi.acm.org/10.1145/2049536.2049612	2011	Poor, G. M.; Leventhal, L. M.; Kelley, S.; Ringenberg, J.; Jaffee, S. D.
S44	Human-Computer Interaction: Overview on State of the Art	Journal	INTERNATIONAL JOURNAL ON SMART SENSING AND INTELLIGENT SYSTEMS (CiteSeerX)	http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.331.6558	2008	Karray, F.; Alemzadeh, M.; Saleh, J. A.; Arab, M. N.

S45	Interactive Educational Games for Autistic Children with Agent-Based System	Journal	Entertainment Computing - ICEC 2005 (Lecture Notes in Computer Science, Springer Berlin Heidelberg)	http://dx.doi.org/10.1007/11558651_41	2005	Sehaba, K.; Estrailier, P.; Lambert, D. none
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